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MINICOMPUTER ASSISTED REPROGRAMMING SYSTEM (MARS)

Horizons Technology, Inc.
7830 Clairemont Mesa Boulevard
San Diego, California 92111

15 December 1979

In-House Report for Period 15 November 1977—15 November 1979

CONTRACT No. DNA 001-78-C-0025

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the work being done on the Minicomputer Assisted Reprogramming System (MARS). MARS provides hand held calculator software development tools, simulators, software translators and code optimizers for the Texas Instruments Model 59 calculator and the Hewlett Packard Models 67 and 97. This report describes two years of software development on these topics and the design of a curve fitting assistance and graphics package also used in the development of calculator software.

CONVERSION FACTORS FOR U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	giga becquerel (GBq)*	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t°f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)**	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbf avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	Gray (Gy)**	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

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I. INTRODUCTION AND SUMMARY

The Department of Defense (DoD) is well aware of the high costs of "scientific" software. The trend of increasing software costs is well established, and for most computer systems the software accounts for 50-90% of the total system cost. In the case of hand-held calculators, the situation is even more extreme as the hardware costs are usually well under $500 and software costs may reach into the tens of thousands of dollars per program. As with most computers, these programs are machine dependent, that is, they will only run on the machine for which they were designed. The rapid developments in the semiconductor industry has created a situation where new calculators are being introduced every 1-3 years. It is desirable to keep these programs running on the current state-of-the-art machines, both from the standpoint of decreased execution time, but also parts, service and technical support from the manufacturer. Because these programs are machine dependent, a substantial amount of code conversion is required to keep these programs operational on the most current machines. This conversion, if done by hand, is costly, error prone and time consuming.

The Minicomputer Assisted Reprogramming System (MARS) was conceived in 1977 to address this problem. MARS provides a hedge against rising software costs and early program obsolescence by providing machine assisted software translation of calculator programs to the new calculator languages rather than a complete recoding of the program. In addition to helping lower the costs of implementing existing programs on new machines, MARS can provide a quicker turn-around time than recoding and provides a means to pool software resources for currently available calculators. Prior to the second year of funding, the MARS concept was reviewed in light of total DNA software requirements. The results of this review revealed that the scope of the project should be broadened to include both general and specific software support tools. As with standard computer software development efforts, software tools are one way to help control costs, decrease development time and insure a quality product.

Prior to the MARS project, no development or support tools for calculator software were available. We undertook the design and development of these tools to assist the calculator programmers in their day-to-day tasks. These tools include an automated "time-space" tradeoff code optimizer, TI-59 and Constant Read Only Memory (CROM) simulator, an algorithm development facility that consists of a sophisticated curve fitting package and support routines and a graphics package that provides for curve fit verification and assists in program verification.

II. HARDWARE AND SOFTWARE

Early during the first year of funding of MARS all of the available options for providing computational services were reviewed. This included a survey of timesharing services and a study of available low-cost minicomputer based systems. Acquisition of a minicomputer was proposed. The reasons included higher system availability, hands-on management of off-line storage, the ability to interface additional peripherals, and if the requirements for the handling of classified data arose, physical accountability of the computer data. Appropriate candidate computer systems were reviewed, bids solicited and a system was chosen. The MARS translation system is based on the Digital Equipment Corp. PDP11T03. The 11T03 system, as ordered, consists of the LSI-11 CPU; KEV-11 bootstrap and diagnostic ROM; 56 kb of MOS RAM; 2 RK05 disk drives and controller organized as one removable disk and one fixed disk in three logical platters for a total of 7.5 Mb of storage on-line; 2 DLV-11 asynchronous serial interfaces; one VT-52 CRT/keyboard and one LS-120 printer/keyboard.

During the second year of funding additional hardware was added to the 11T03 to provide graphics input and output capability. This hardware consists of a Summagraphics BP-11 "Bitpad" digitizing tablet, cursor, power supply and RS232 interface; a DLV-11F single channel RS232 interface; Hewlett Packard 7225A X-Y plotter and IBV-11A IEEE-488 interface. The 11T03 system with peripherals has functioned normally and has proven to be quite reliable.

All MARS software is written and designed for interaction with DEC's RT-11 operating system. Version 3-02 is used by MARS and provides all functions normally associated with operating systems including overlay capability and disk file management. From the outset of the MARS project the requirements for portability and maintainability of the applications software have been undefined. As a consequence, all routines, with a few exceptions, have been coded using DEC's version of ANSI standard Fortran IV for portability, readability and maintainability.

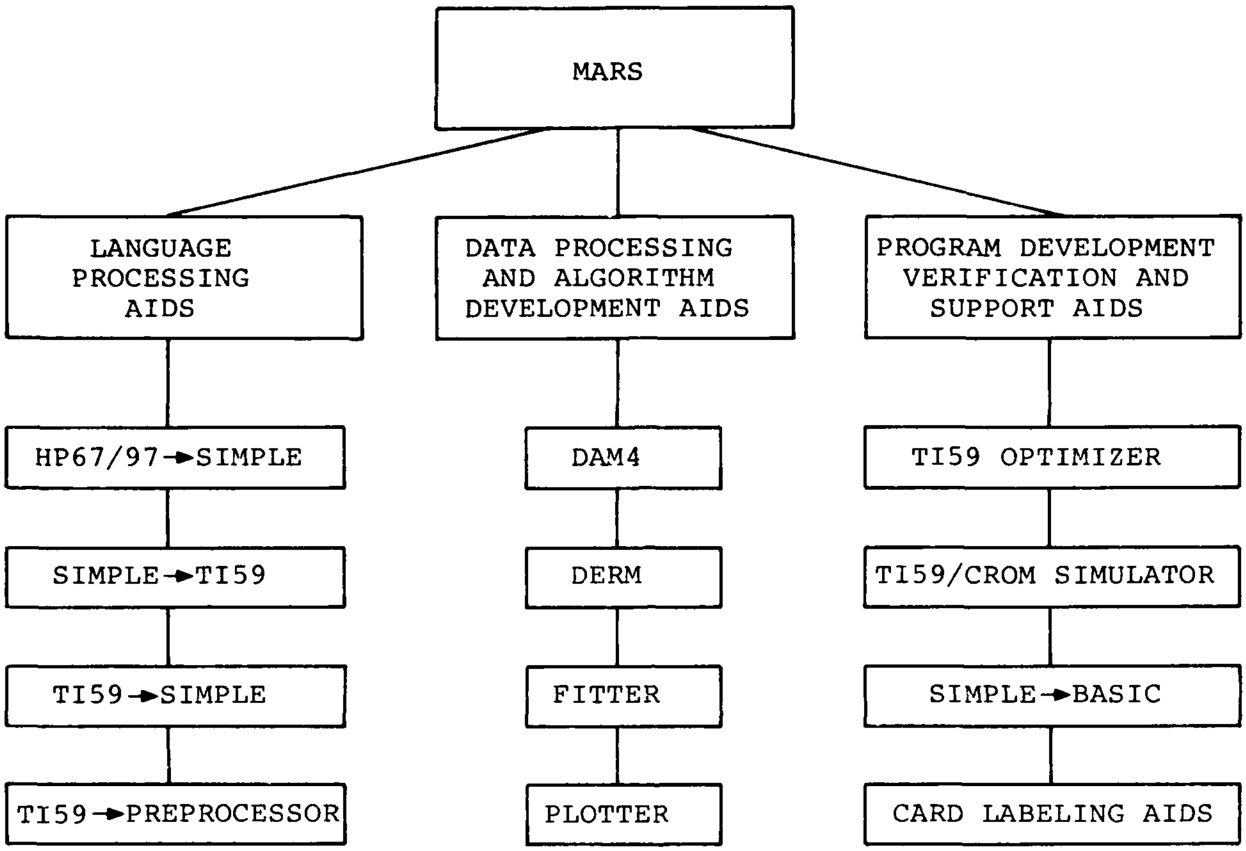
Initial MARS software development was done using DEC's Fortran IV V2.04, but the discovery of several compiler "bugs" and shortcomings has forced us to upgrade to version 2.1. In addition to Fortran, the MARS algorithm verification facility uses DEC's single user BASIC version 1. All MARS files are written in the Standard RT-11 file format and, where appropriate, are written using ASCII code for human readability.

III. TECHNICAL APPROACH

MARS was originally conceived as a language translation aid to help provide a hedge against the obsolescence of calculator based scientific software. As the system design progressed and more experience was gained in the processing of calculator software, it became obvious that the original concept could, and should, be expanded to provide automated support in other areas of the calculator software development task. During the second year of funding, additional features were incorporated into the existing software system. As can be seen by Figure 1, the MARS system currently consists of three functional areas: the Language Processing aids; Data Processing and Algorithm development aids; and Program Development, Verification and Support aids. A description of the purpose, implementation and a brief functional description of each of the component modules follows. Appendices A-1 through C-4 contain listings of these modules and a more complete description of the operation of the module as program comments. Where appropriate, examples will be included in this section of the report to demonstrate critical technical points.

III-A. MARS Language Processing Modules

This group of Fortran IV modules comprises the bulk of the implementation of the original MARS concept. The basic idea was to provide an expedient, machine assisted method for making existing calculator programs executable on newer or more sophisticated calculators. At the outset of the project, only two manufacturers, Hewlett Packard (HP) and Texas Instruments (TI), were producing hand-held personal programmable calculators (HHPPC) with enough capabilities for DNA's software tasks. Our studies revealed vast, fundamental differences in the programming and operation of these two classes of machines. Furthermore, it was not clear whether other manufacturers might market models with the necessary capabilities. As a consequence, it became

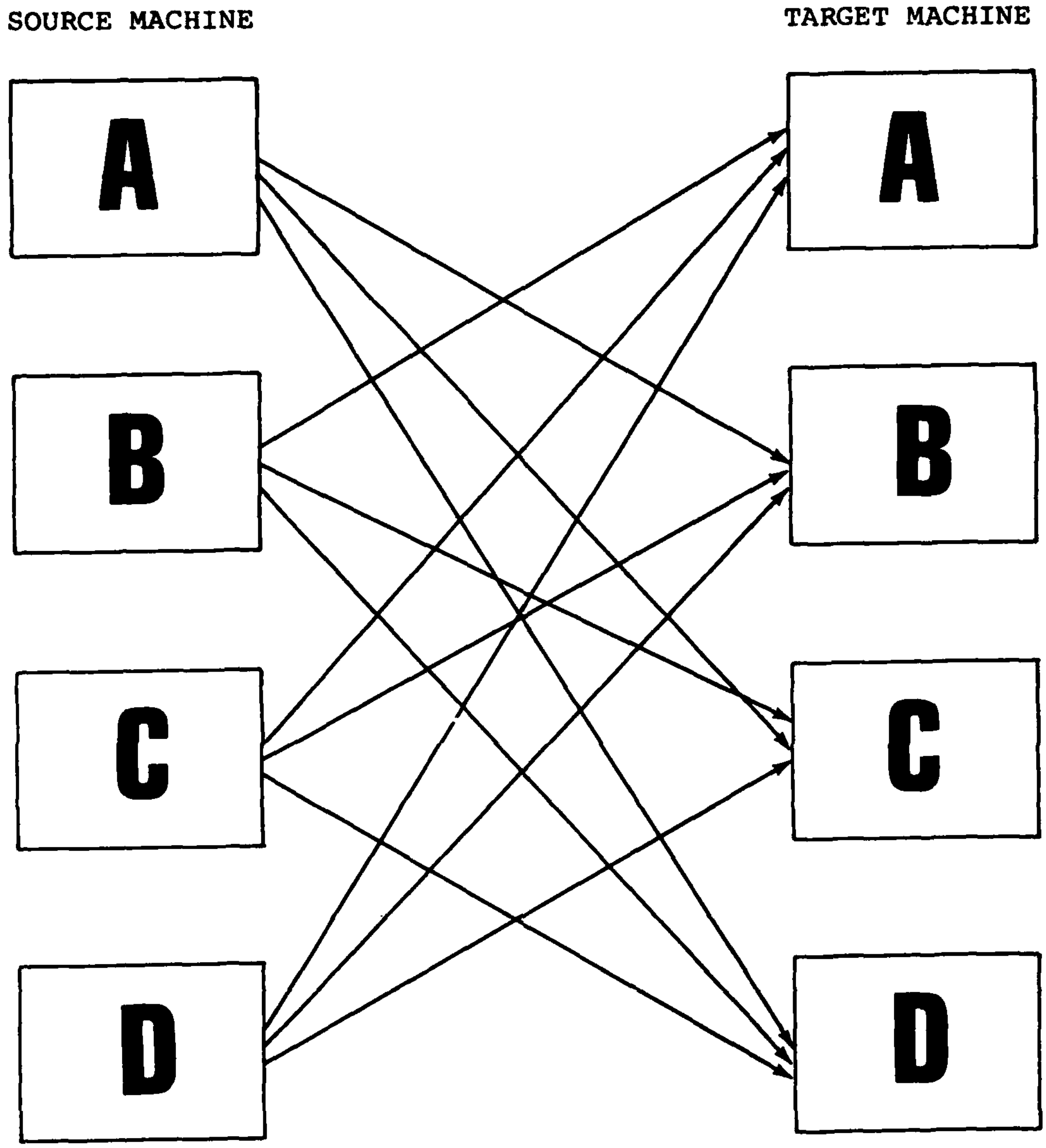


MARS CAPABILITIES ORGANIZED BY FUNCTIONAL AREAS

Figure 1.

apparent that our solution to the language translation problem would have to be general purpose in nature and very expandable. Additional system design parameters were gained through the insight that if one were to implement a single purpose "point-to-point" translator to provide the ability to go from machine A to machine B, and there exist N machines, then the number of translator modules required increases as N^2-N (Figure 2). However, if one could design a general purpose intermediate language, all translations could be made through this language and the number of translator modules only increases as 2N (Figure 3). During the analysis phase of MARS, HP and TI were each releasing new machines on a two-year design cycle, one year out of phase with each other. The result was that a new, more powerful machine was being released each year from alternating manufacturers. This situation, coupled with the fact that each manufacturer had two machines in the field, pointed strongly to the intermediate language solution being the best. As an additional benefit to this solution, the intermediate language provides a convenient storage mechanism for translated programs and provides the ability to modify and optimize the program in its intermediate form. Furthermore, this solution provides for unlimited future expansion in terms of the number of source and target machines that can be handled.

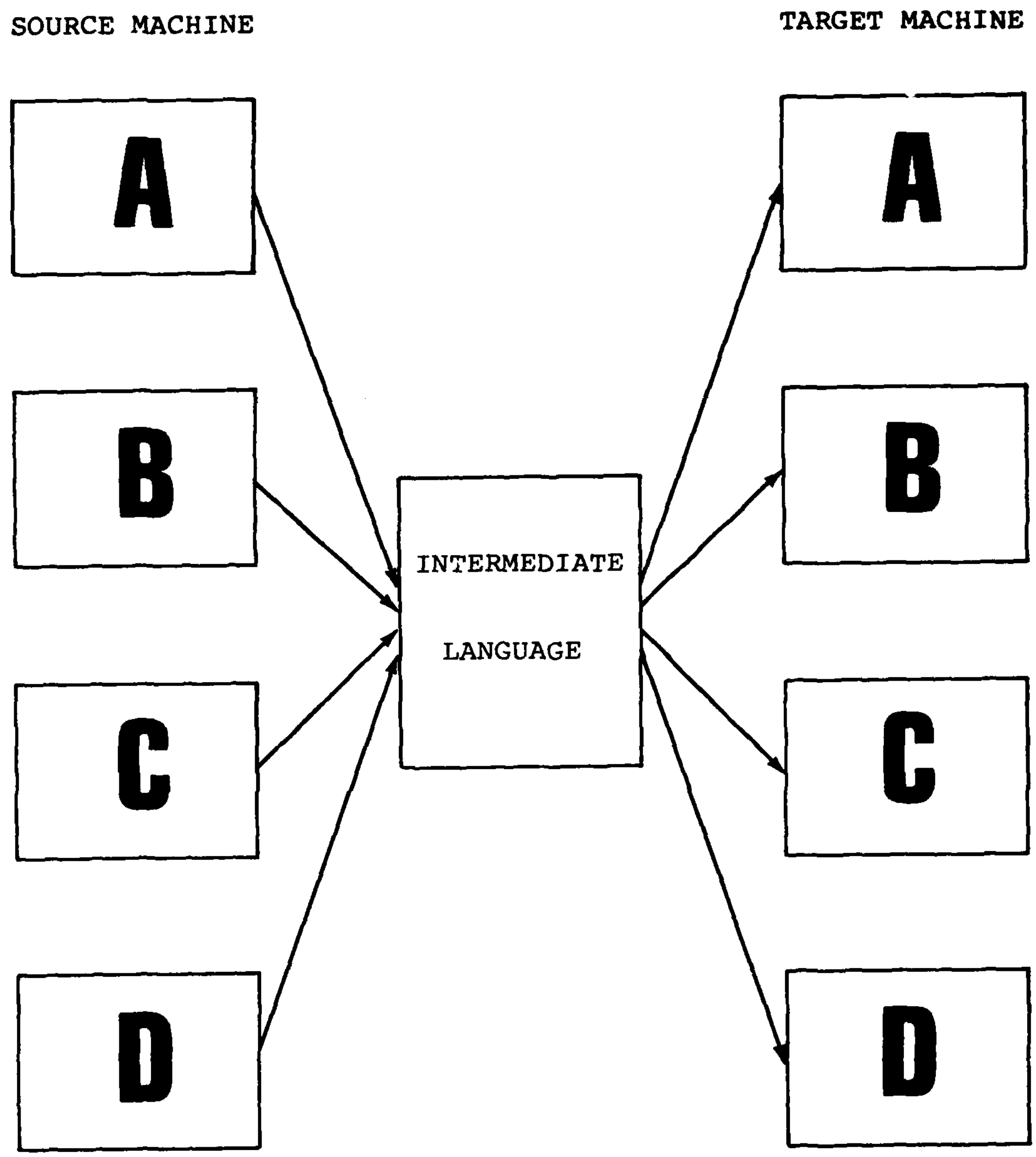
Several existing languages were considered as candidates for the intermediate language. All were discarded due to data formatting problems and overall complexity of the finished program. We, instead, opted to design our own intermediate language. Our prime design considerations were human readability, simplicity and ease of translation. The completed design of SIMPLE (for Special Interpretative Mathematical Programming Language Experiment) contains constructs for all calculator based mathematical operators, addressing modes, and transfers of address. The most complex expression allowed in SIMPLE is of the form "A = B + C". Expressions that are more complex are decomposed by parsing until they are in this elementary form. The main advantage of this form is that it promotes human readability and facilitates machine



Number of Modules = $4^2 - 4 = 12$

Point-to-Point Translation Approach

Figure 2.



Number of Modules = 2 × 4 = 8

Intermediate Language Translation Approach

Figure 3.

manipulations of expressions. Generally speaking, the translation process requires two steps to complete a source to target translation. Step one is to translate from the source code syntax into a form compatible with the syntax of SIMPLE. The second step is to translate from SIMPLE to a form acceptable to the target machine. This arrangement provides for stand-alone operation of each translation module. All processing modules communicate with each other via disk files using the standard MARS file format. Since each module is designed for stand-alone operation, and no two modules are core resident simultaneously, an unlimited number of modules can be added between any two processing end points. This concept insures expandability to any desired degree, and will help protect the system from obsolescence.

The language processing portion of MARS has been divided into four modules. The modules provide the ability to move source code to and from the SIMPLE language. The modules provide the capability to translate from HP67/97 code to SIMPLE (HP67/97 decompiler); from TI59 code to an intermediate in-line TI59 code (TI preprocessor); from TI59 in-line code to SIMPLE (TI59 decompiler); and from SIMPLE to TI59 (TI59 recompiler). Due to the radically different methods of problem representation of the two manufacturers, i.e., RPN vs. AOS, large difficulties in the translation process have been encountered. Both systems perform problem evaluation in an interpretive manner using stack oriented processing for expression parsing and the actual numerical evaluation. In the HP case, the stack processing in an integral part of the machine and actively manipulated by the programmer. All operators are executed as they are encountered and operate on data that resides in the stack at the time the operator is encountered in the program. For the TI machines, stacks also exist, but are implicit in the operation of the machine. Because the AOS representation of the task is not immediately executable by the machine, a large amount of parsing must be done to allow evaluation of the expression. This parsing revolves around the use of two stacks, one for data and one for pending operations (in AOS not all operators are executed as they are encountered.) The problem centers around the fact that both machines allow transfers of address at any place in the code -- even within the middle of equations or expressions. Although this is a very powerful tool when used properly, it presents a formidable task for the language translators. The evaluation of any expression is determined by the "data" in the stack(s), and since the translators must perform a partial evaluation, the translation process is determined, or at least affected, by the data in the stack(s). The problem is further compounded by the fact that TI allows transfers of address with pending data and operators. The straight-forward solution is obvious but results in an unacceptably large translated program. This method calls for the evaluation of each alternate course of program flow in the code, taking into account the possible changes in the values in the stack(s). Each alternate course (branch, jump, subroutine call or reset) requires evaluation all the way to the completion of the program. The result is that a relatively straight-forward input code is transformed into a huge "tree" with a "branch" "growing" to the end of the program at each alternate course of action. For the HP67/97 the problem has been solved in an expeditious manner. It involves five complete "translations" and a substantial amount of code compaction, including both local and global variable minimizations. With the exception of testing all possible code sequences, the HP67/97 decompiler is complete. Furthermore, our tests show that for many code sequences, the translated code is optimal (i.e., no unnecessary steps). The TI59 language processors are near complete. With the exception of extensive testing, the TI59 decompiler is complete. However, this presupposes the existence of in-line code. This conversion to in-line code is the responsibility of the preprocessor. Most of the services required of the preprocessor, i.e., input editing constant and digit manipulation and subroutine expansion, are available. However, due to the extreme complexity of the "pending op" problem, this feature is unavailable. Furthermore, since the need to translate large numbers of TI59 codes to other machines has not yet occured, this task has been deferred and resources have been redirected to other more pressing problems. See Appendix A2 and A3 for more details on the TI59 preprocessor and decompiler.

The last segment of the language processing modules is the TI59 recompiler. The recompiler takes as input the intermediate language representation of the program and converts it to a form acceptable to the TI59. The recompiler attempts to exploit all the capabilities of the TI59 and performs an "inverse parsing" function in that it recreates statements with parentheses under the precedence constraints of the TI59. The output of the recompiler is an unoptimized, linear program sequence that is executable but inefficient. This module is complete, except for two argument numerical functions and indirect transfers of address. It is felt that these problems are best resolved by human assistance, since complete automation of these functions would be excessively expensive. The recompiler has been tested for elementary code sequences required for validation of the algorithm. Due to the excessive amount of time required to synthesize test programs, evaluate the source and output for validity and efficiency, it is recommended that further work on this phase be deferred until such time as "production" translation programs become available. This method will save the cost of test program synthesis and provide a more realistic basis for validation.

III-B. MARS Data Processing and Algorithm Development Modules

During the second year of funding, the scope of the MARS project was expanded to include NWE programming aids. More specifically, the four modules that comprise this functional group combine to provide the NWE programmer with a comprehensive set of tools to assist him in numerical modeling of nuclear phenomenology. Many of the tasks encountered by the NWE staff entail the representation of empirically and theoretically produced data in a form that will fit in the HHPPC. More often than not, this results in the approximation of sets of graphs and tables of numbers by a family of equations. This task is collectively referred to as "curve fitting". Manual fitting of large amounts of data is costly and error prone. Therefore, we have undertaken, and completed, the development of a group of programs to assist the NWE staff in their curve fitting efforts. The process of fitting curves can be functionally divided into four parts. The first task is acquisition of data from the curve to be fit. To do this acquisition manually requires the use of a backlighted table, high resolution graph paper and lots of patience. We have resolved this problem with the use of an electronic digitizing tablet and necessary computer interface circuitry and software. The tablet provides an 11" x 11" active area with 2200 points resolvable in each direction resulting in a resolution of .0005". Coordinate information, as specified by the operator using a stylus or cross-haired cursor, is transformed to a four digit ASCII absolute tablet coordinate (ATC) and transmitted to the 11T03 via an RS232 interface. Since without scaling information the ATC data is useless, we have combined several management functions into one module for data acquisition. This module, DAM4, for Data Acquisition Module version four, is an interactive Fortran IV program that provides a variety of services. It allows for calibration of the tablet, compensation for translation, rotation and scaling of the graph using a sophisticated multi-point, least squares coordinate transformation, and provides for the entering of axis label information and data file management including multiple curves per file. The result of a session using DAM4 is a formatted ASCII disk file containing the coordinate data for points selected by the user. This data file is passed on to the next link in the processing chain -- DERM.

DERM stands for Data Edit and Review Module, and is an interactive program that does as the name implies. DERM uses the output file from DAM4 as input and provides the user with the ability to quickly review the digitized data for smoothness and accuracy, perform single and double argument immediate transformations on the data, insert, delete and change data points, list data on the printer and produce "quick" plots of the data for visual evaluation. Furthermore, DERM has the capability to provide for the linking and unlinking of related data files and allows for data inversion on families of graphical data in either single or multi-file format. As its output DERM produces a data file with corrected points that is passed on to the Fitter module.

The fitter module is the crux of the data processing package in that this module is responsible for the actual curve fitting. Unlike earlier attempts at an automated curve fitter, we have kept the human "in the loop" to insure a reasonable choice of base function and resultant coefficients. The actual task of fitting numerical data is distributed over five submodules. The first submodule is responsible for disk file input/output and provides the user with dynamic editing capabilities as well as immediate data transforms and scratch pad management functions. Submodule two is the actual curvefitting routines. Submodule three is the function form definition module. The user has the ability to choose any of 60 "prepackaged" base function forms as well as any one of five user defined forms. The functional form choices include polynomial, logarithmic, normal distribution, inverse cumulative normal distribution and Legendre polynomials. Submodule four is the function evaluation module. In addition to being able to evaluate the fitting function given the function form, this submodule gives the user the ability to choose coefficient initial values, search intervals and starting values. Additionally, the search routine can be constrained according to user specified criterion, like mean square error or maximum error. It also allows evaluation of the function at user-defined initial values and intervals, and can store these values for use by the plot module. The fifth submodule is a data smoother.

This allows the user to represent the given data using cubic spline techniques to provide for function evaluation at periodic intervals of the independent variables. This, then, provides an ordered, periodic sampled data base for the fitter submodule.

The final module in the Data Processing package is the Plot module. This module allows the user to produce high quality plots, including alphanumeric and axis data, on the HP7225A X-Y plotter. The plot module uses as input files produced by DAM4, DERM, Fitter or the user and generates plots of the ordered data on 8½" x 11" paper. The plot module attempts to use the parameters contained with the data file to define all the "particulars" of the plot -- like size, orientation, axis scaling, etc. The user has the ability to override the defaults at any time. This module allows linear, logarithmic or user-defined axes in both X and Y directions, variable length and size of axis and plot labels, automatic or manual axis value numbering, horizontal or vertical orientation, variable finished plot size and the ability to plot multiple curves and/or multiple files of data on the same plot. Additionally, the module has the ability to plot on pre-ruled graph paper by using the reverse communication link to the 11T03 for graph orientation data. A complete sample run of the Data Processing modules is contained in Section IV of this report.

III-C. Program Development, Verification and Support Modules

The four modules in this group provide general program development support. The first module is the TI59 optimizer. This module, as its name implies, allows programs written for the TI59 to be optimized according to known operational parameters of the calculator. Designed originally as a post-processor for the TI59 Recompiler, this module uses as input a disk file generated as output of the recompiler or prepared with the RT-11 editor EDIT or TECO, or human-entered keyboard data. The optimizer exploits known idiosyncracies of the operation of the TI59 to perform an "execution-time program size" tradeoff. This time-space optimization technique evaluates the tradeoffs between fast execution of in-line code versus the slower execution of more compact subroutinized code. Based on operator input parameters, subroutines are formed out of repeated keystroke sequences, literal digit strings are formed into register based constants where the literal digits are replaced by a register recall, and subroutines are organized in the calculator's memory space according to length, calling frequency and overhead. The resultant code executes as fast as possible for a given program size. This module is complete.

To provide for verification of translated programs and assistance in the design of Constant Read Only Memories (CROM) for the TI59, a full function simulator has been developed. This module is, in actuality, a software development aid in addition to a verification scheme and consists of a keyboard monitor, multi-mode debugger, main memory simulator and CROM memory simulator. The simulator provides all the computational abilities of the TI59 plus single step execution, trace mode, text editing including "block move" instructions, a CROM paging scheme and formatted disk input/output including the processing of manually entered CROM images. This module is operational, however, several enhancements may be desired to improve its operator interface and usefulness.

To provide an automated basis for SIMPLE program verification, and provide production translation capabilities should the need arise, we have developed the capability to translate from SIMPLE to RT-11 single user BASIC. Although not intended as a true MARS language processor, this module is easily enhancable to that state. Input to the program is a MARS language processor format disk file containing SIMPLE code. A file of this type is produced by any of the language decompilers. The output of the processor is a disk file that conforms to that which is expected by the RT-11 BASIC interpreter. This module is complete and the implications of its function are obvious. As new generations of HHPPC's are developed it is most likely that many will use BASIC rather than a keystroke based language. We now have the capability to perform the necessary language translations when the need arises.

The last module in this group is a magnetic card writing aid. The hand-printing of small quantities of custom cards has always been a problem. The space allotted for labeling is small so hand-lettered labels become virtually unreadable. This program uses the HP7225A plotter and digitizing sight, in conjunction with the CRT to provide a quick and convenient method of labeling small quantities of magnetic cards. This module is complete.

IV. SAMPLE RUN OF THE CURVEFITTING PACKAGE, INCLUDING USE OF DAM4, DERM, FITTER, AND HP7225 PROGRAMS

This example demonstrates the use of the programs in the curvefitting and plotting package. A source graph from the DNA EM-1 effects manual is digitized, the units are transformed, a functional form is fitted to the data, and the resultant fit is plotted against the original for verificati

Each step in this example illustrates the capabilities of a different program in the package, and also defines a particular task in the data fitting process. The text of this example combines actual output from the programs with an explanation of the results and of the task itself. In the program output, the user's responses to the program's requests have been underlined so that they may be distinguished from the program materia

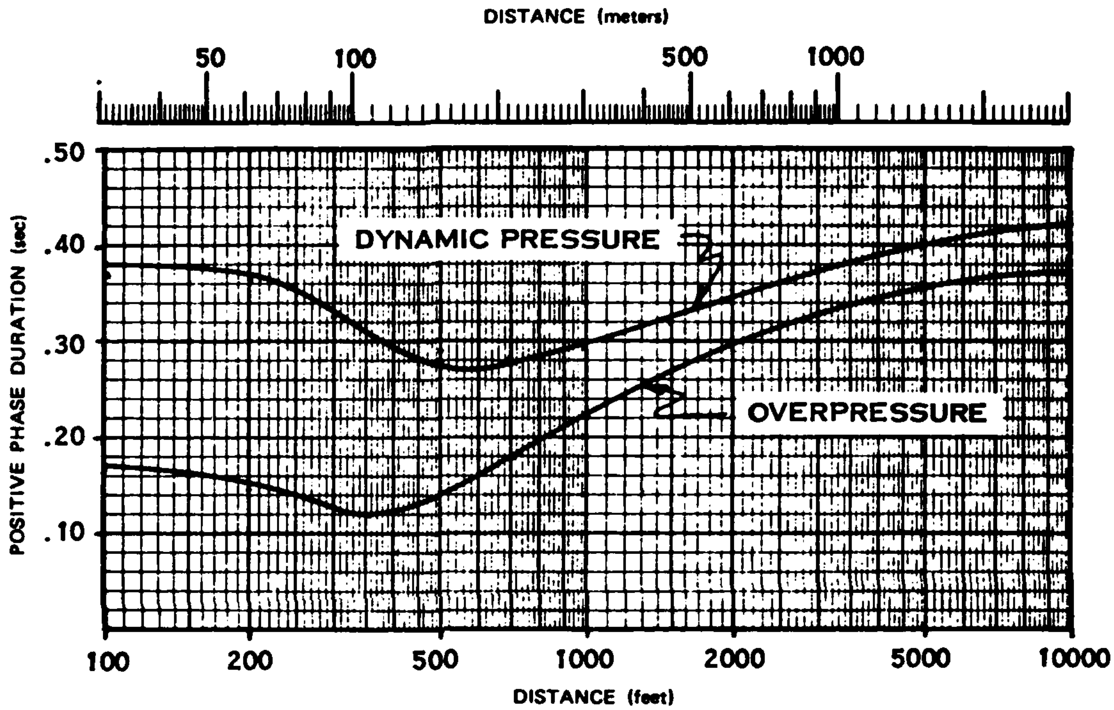
STEP 1.

The graphical data is digitized and a data file produced by DAM4 (the Data Acquisiton Module.)

The data to be fitted is taken from the DNA/EM-1 effects manual (see Fig. 4), giving the duration for the positive phase in free-air overpressure as a function of distance from the explosion. To convert the graphical data into numeric data to be used by the other programs, DAM4 is used in conjunction with a digitizing tablet.

The object of DAM4 is to produce a disk file containing digitized dat and relevant parameters, including axes labels, axes types (as, for example, logarithmic scales), minimum and maximum data values, and the names of other associated data files. Excerpts from the working session with DAM4 show how this is accomplished:

```
 PLEASE ENTER OUTPUT FILENAME: DURPP.DAT

 PLEASE ENTER GRAPH NAME WITH
 64 CHAR LIMIT: DURATION OF POSITIVE PHASE, OVERPRESSURE & DYN PRESSURE

 (FOR POLAR PLOTS RADIUS IS X, ANGLE IS Y)
 (LOGRTH MEANS LOGARITHMIC, USERDF MEANS USER DEFINED)

 SELECT DESIRED GRAPH TYPE....

 ....FROM FOLLOWING MENU FOR X-Y PLOT

  000   LINEAR IN X, LINEAR IN Y
  010   LINEAR IN X, LOGRTH IN Y
  020   LINEAR IN X, USERDF IN Y
  100   LOGRTH IN X, LINEAR IN Y
  110   LOGRTH IN X, LOGRTH IN Y
  120   LOGRTH IN X, USERDF IN Y
  200   USERDF IN X, LINEAR IN Y
  210   USERDF IN X, LOGRTH IN Y
  220   USERDF IN X, USERDF IN Y

 ....FOLLOWING MENU FOR POLAR PLOT

  301   POLAR PLOT WITH ANGLE IN RADIANS
  311   POLAR PLOT WITH ANGLE IN DEGREES

PLEASE ENTER THE GRAPH TYPE (3 DIGITS AS SHOWN): 100
```



Duration of Positive Overpressure and Dynamic Pressure Phases for a 1 kt Free Air Burst in a Standard Sea Level Atmosphere

Figure 4.

```
WE NEED MINIMUM AND MAXIMUM VALUES IN X AND Y
FOR THE GRAPH AS A WHOLE, PLEASE ENTER THESE AS REAL
NUMBERS (WITH EXPLICIT DECIMAL POINT)

ENTER XMIN: 100.
ENTER XMAX: 10000.

ENTER YMIN: 0.
ENTER YMAX: .5

LABEL FOR X AXIS?
64 CHAR LIMIT: DISTANCE (FT)

LABEL FOR Y AXIS?
64 CHAR LIMIT: POS. PHASE DURATION (SEC)

WILL A NEXT DATA FILE BE ASSOCIATED WITH THIS FILE?
IF YES, ENTER ITS NAME, ELSE ENTER CARRIAGE RETURN ONLY

FILENAME IS:                (carriage return)

WAS THERE A LAST DATA FILE ASSOCIATED WITH THIS FILE?
IF YES, ENTER ITS NAME, ELSE ENTER CARRIAGE RETURN ONLY

FILENAME IS:                (carriage return)
```

In order to translate the internal coordinates of the digitizing tablet into those of the graph, an algorithm is used which orients and scales the tablet's output, based on the designated coordinates of at least three points on the tablet. (Three points will determine the axes uniquely; more than three can be used in an averaging scheme to allow for human imprecision and for nonlinearities and skewed axes in the graphs themselves.)

```
HOW MANY INDIVIDUAL CURVES WILL BE ON THIS GRAPH: 2

TO CALIBRATE THE BIT PAD WE WILL NEED 3 OR MORE
WIDELY SEPARATED POINTS, HOW MANY SUCH POINTS SHALL
WE USE: 4

AFTER EACH POINT IS ENTERED YOU MUST TELL ME THE
DESIRED X AND Y VALUES FOR THE POINT.

                                        DIGITIZE A POINT

INPUT VALUES FOR X AND Y: 110.,.02

                                        DIGITIZE A POINT
```

```
INPUT VALUES FOR X AND Y: 110.,.46

                                                  DIGITIZE A POINT

INPUT VALUES FOR X AND Y: 9200.,.02

                                                  DIGITIZE A POINT

INPUT VALUES FOR X AND Y: 9200.,.46
```

Now the data values are digitized directly, assigning a weight to each point:

```
EACH CURVE MIGHT POSSIBLY REQUIRE SEVERAL PARAMETERS
FOR SUBSEQUENT PROCESSING BY OTHER PROGRAMS.  THE
PRESENT PROGRAM WILL ACCEPT WHATEVER YOU INPUT...

THE SUGGESTED FORM IS ONE OR MORE NUMERICAL FIELDS
EACH ENDING WITH A COMMA WITH ANY DESIRED CHARACTERS
FOLLOWING THE RIGHTMOST (OR ONLY) COMMA.....

PLEASE ENTER DATA CONTROL FIELD FOR THIS CURVE WITH
64 CHAR LIMIT: 1., (OVERPRESSURE)

YOU MAY NOW INPUT POINTS FROM THE DIGITIZER.
AFTER EACH POINT YOU WILL BE ASKED FOR A WEIGHTING
FACTOR, IF YOU ARE MERELY TESTING OR WISH TO DISCARD
THE POINT, YOU SHOULD GIVE A WEIGHT OF ZERO.  MOST
USUALLY THE WEIGHT WILL BE ONE.  A NEGATIVE WEIGHT
WILL BE ACCEPTED AS A SIGNAL TO EITHER RECALIBRATE
(WEIGHT=-1) OR TO END THIS PARTICULAR CURVE
(WEIGHT=-2) (WITHIN THE SAME FAMILY).

A CARRIAGE RETURN ALONE GIVES A WEIGHT OF ONE.

SELECT POINT ON DIGITIZER
                   X IS   103.89          Y IS   0.16981
WEIGHT? :1

                                    TO DISK

SELECT POINT ON DIGITIZER
                   X IS   117.68          Y IS   0.16761
WEIGHT? :1

                                    TO DISK

   .

   .

   .
```

```
SELECT POINT ON DIGITIZER
                        X IS   8987.1              Y IS   0.36950
WEIGHT? :1

                                                TO DISK

SELECT POINT ON DIGITIZER
                        X IS   654.17              Y IS   -0.40655  (sarbase)
WEIGHT? :-2

LAST POINT DISCARDED, *** END OF CURVE SIGNAL ***
```

The procedure is repeated for the second curve (dynamic pressure). After the last point has been digitized, DAM4 writes the completed file of data points in a standard format for use by the other programs.

.

.

.

```
SELECT POINT ON DIGITIZER
                        X IS   9635.8              Y IS   0.41904
WEIGHT? :1

                                                TO DISK

SELECT POINT ON DIGITIZER
                        X IS   5014.6              Y IS   -0.35513  (sarbase)
WEIGHT? :-2

LAST POINT DISCARDED, *** END OF CURVE SIGNAL ***

DISK FILE WRITTEN AND CLOSED, BYE FOR NOW

STOP --  IN PROGRAM DAM4
```

The resultant disk file:

```
FILE:DURPP.1DF  DATE:30-NOV-79 16:04
NAME:POSITIVE PHASE DURATION. OVERPRESSURE & DYN PRESSURE
TYPE:100
X(MIN,MAX):       1.0000000E+02,       1.0000000E+04
Y(MIN,MAX):       0.0000000E-01,       5.0000000E-01
X LABEL:DISTANCE (FT)
Y LABEL:POS. PHASE DURATION (SEC)
NEXT FILE:
LAST FILE:
```

```
SOF     2
SOC 1., (OVERPRESSURE)
         1.0389166E+02,         1.6980615E-01,   1.
         1.1767580E+02,         1.6761231E-01,   1.
         1.3443927E+02,         1.6539657E-01,   1.
         1.5292946E+02,         1.6225377E-01,   1.
         1.7395361E+02,         1.5629689E-01,   1.
         1.9534042E+02,         1.5224892E-01,   1.
         2.2219490E+02,         1.4629205E-01,   1.
         2.6044104E+02,         1.3650638E-01,   1.
         2.9878143E+02,         1.2677549E-01,   1.
         3.3549152E+02,         1.1897544E-01,   1.
         3.9502335E+02,         1.2137309E-01,   1.
         4.5333554E+02,         1.3040265E-01,   1.
         5.2027411E+02,         1.4130826E-01,   1.
         6.1280017E+02,         1.6152833E-01,   1.
         7.2178143E+02,         1.8174841E-01,   1.
         8.4649774E+02,         2.0197943E-01,   1.
         9.7575928E+02,         2.1756418E-01,   1.
         1.1642219E+03,         2.3868941E-01,   1.
         1.4192300E+03,         2.5882182E-01,   1.
         1.6643999E+03,         2.7717680E-01,   1.
         1.9434152E+03,         2.9179066E-01,   1.
         2.3185310E+03,         3.0728772E-01,   1.
         2.8140056E+03,         3.2274100E-01,   1.
         3.4594993E+03,         3.3534732E-01,   1.
         4.4018110E+03,         3.4786597E-01,   1.
         5.5764814E+03,         3.5758150E-01,   1.
         6.6231509E+03,         3.6370933E-01,   1.
         7.6986499E+03,         3.6707789E-01,   1.
         8.9871709E+03,         3.6949745E-01,   1.
EOC
SOC 2., (DYNAMIC PRESSURE)
         1.0430090E+02,         3.7898505E-01,   1.
         1.2546711E+02,         3.7757584E-01,   1.
         1.4963704E+02,         3.7618852E-01,   1.
         1.7922218E+02,         3.7197620E-01,   1.
         2.0650964E+02,         3.6692446E-01,   1.
         2.5265778E+02,         3.5140106E-01,   1.
         2.9992636E+02,         3.3032629E-01,   1.
         3.6216669E+02,         3.0264145E-01,   1.
         4.3739233E+02,         2.8339887E-01,   1.
         5.0608652E+02,         2.7083200E-01,   1.
         5.8067072E+02,         2.6860529E-01,   1.
         6.7789386E+02,         2.7383891E-01,   1.
         8.2979028E+02,         2.8458017E-01,   1.
         9.7718799E+02,         2.9541999E-01,   1.
         1.2814858E+03,         3.1442809E-01,   1.
         1.7096489E+03,         3.3245435E-01,   1.
         2.0660352E+03,         3.4604251E-01,   1.
         2.5841709E+03,         3.6235708E-01,   1.
         3.2320801E+03,         3.7585759E-01,   1.
         4.1302988E+03,         3.9024132E-01,   1.
         5.2552368E+03,         4.0182194E-01,   1.
```

```
        6.5159072E+03,         4.0971622E-01,  1.
        7.7386191E+03,         4.1396800E-01,  1.
        9.6358232E+03,         4.1903728E-01,  1.
EOC
EOF
```

STEP 2.

The digitized data is reviewed and modified using program DERM (the Data Edit and Review Module).

DERM reads the file and allows inspection of the data and file parameters:

```
DERM version 2 is ready.  Type ? for information.

>READ DURPP.1DF

Z    1.00000
Z    2.00000
 53 points in data buffer.

>HEADER

FILE    :  DURPP.1DF
DATE    :  30-NOV-79
TIME    :  16:04
NAME    :  POSITIVE PHASE DURATION, OVERPRESSURE & DYN PRESSURE
TYPE    :  CARTESIAN

XLABEL  :  DISTANCE (FT)
XAXIS   :  LOGRITHMIC
XMIN    :  1.00E+02
XMAX    :  1.00E+04

YLABEL  :  POS. PHASE DURATION (SEC)
YAXIS   :  LINEAR
YMIN    :  0.00E-01
YMAX    :  5.00E-01

NEXT    :
LAST    :

>LIST
              X               Y               Z
   1       103.892        0.169806        1.00000
   2       117.676        0.167612        1.00000
   3       134.439        0.165397        1.00000
   4       152.929        0.162254        1.00000
   5       173.954        0.156297        1.00000
   6       195.340        0.152249        1.00000
   7       222.195        0.146292        1.00000
   8       260.441        0.136506        1.00000
   9       298.781        0.126775        1.00000
  10       335.492        0.118975        1.00000
  11       395.023        0.121373        1.00000
  12       453.336        0.130403        1.00000
```

13	520.274	0.141308	1.00000
14	612.800	0.161528	1.00000
15	721.781	0.181748	1.00000
16	846.498	0.201979	1.00000
17	975.759	0.217564	1.00000
18	1164.22	0.238689	1.00000
19	1419.23	0.258822	1.00000
20	1664.40	0.277177	1.00000
21	1943.42	0.291791	1.00000
22	2318.53	0.307288	1.00000
23	2814.01	0.322741	1.00000
24	3459.50	0.335347	1.00000
25	4401.81	0.347866	1.00000
26	5576.48	0.357582	1.00000
27	6623.15	0.363709	1.00000
28	7698.65	0.367078	1.00000
29	8987.17	0.369497	1.00000
	X	Y	Z
30	104.301	0.378985	2.00000
31	125.467	0.377576	2.00000
32	149.637	0.376189	2.00000
33	179.222	0.371976	2.00000
34	206.510	0.366924	2.00000
35	252.658	0.351401	2.00000
36	299.926	0.330326	2.00000
37	362.167	0.302641	2.00000
38	437.392	0.283399	2.00000
39	506.087	0.270832	2.00000
40	580.671	0.268605	2.00000
41	677.894	0.273839	2.00000
42	829.790	0.284580	2.00000
43	977.188	0.295420	2.00000
44	1281.49	0.314428	2.00000
45	1709.65	0.332454	2.00000
46	2066.04	0.346043	2.00000
47	2584.17	0.362357	2.00000
48	3232.08	0.375858	2.00000
49	4130.30	0.390241	2.00000
50	5255.24	0.401822	2.00000
51	6515.91	0.409716	2.00000
52	7738.62	0.413968	2.00000
53	9635.82	0.419037	2.00000

>

We will discard the second curve (dynamic pressure) for now, and convert the distance (X) from feet to meters:

>DELETE 30-

>MULT .3048 X

```
>LIST
              X             Y            Z
  1        31.6662      0.169806      1.00000
  2        35.8676      0.167612      1.00000
  3        40.9771      0.165397      1.00000
  4        46.6129      0.162254      1.00000
  5        53.0211      0.156297      1.00000
  6        59.5398      0.152249      1.00000
  7        67.7250      0.146292      1.00000
  8        79.3824      0.136506      1.00000
  9        91.0686      0.126775      1.00000
 10        102.258      0.118975      1.00000
 11        120.403      0.121373      1.00000
 12        138.177      0.130403      1.00000
 13        158.580      0.141308      1.00000
 14        186.781      0.161528      1.00000
 15        219.999      0.181748      1.00000
 16        258.013      0.201979      1.00000
 17        297.411      0.217564      1.00000
 18        354.855      0.238689      1.00000
 19        432.581      0.258822      1.00000
 20        507.309      0.277177      1.00000
 21        592.353      0.291791      1.00000
 22        706.688      0.307288      1.00000
 23        857.709      0.322741      1.00000
 24        1054.46      0.335347      1.00000
 25        1341.67      0.347866      1.00000
 26        1699.71      0.357582      1.00000
 27        2018.74      0.363709      1.00000
 28        2346.55      0.367078      1.00000
 29        2739.29      0.369497      1.00000

>
```

The header is changed accordinginly, and the modified data is given the new filename DURPP.2DF:

```
>XLABEL DISTANCE (M)

>XMIN 30.

>XMAX 3000.

>FILE DURPP.2DF

>NAME POSITIVE PHASE DURATION, OVERPRESSURE

>HEADER

FILE    :  DURPP.2DF
DATE    :  30-NOV-79
TIME    :  16:04
NAME    :  POSITIVE PHASE DURATION, OVERPRESSURE
```

```
TYPE    :  CARTESIAN

XLABEL :  DISTANCE (M)
XAXIS  :  LOGRITHMIC
XMIN   :  3.00E+01
XMAX   :  3.00E+03

YLABEL :  POS. PHASE DURATION (SEC)
YAXIS  :  LINEAR
YMIN   :  0.00E-01
YMAX   :  5.00E-01

NEXT   :
LAST   :

>
```

Finally, the modified data, which is ready to be fit, is written into a disk file of the standard format:

```
>WRITE

Z   1.00000
 29 Points written.

>BYE
```

The resulting file is:

```
FILE:DURPP.2DF  DATE:30-NOV-79 16:04
NAME:POSITIVE PHASE DURATION, OVERPRESSURE
TYPE:100
X(MIN,MAX):         3.000000E+01,         3.000000E+03
Y(MIN,MAX):         0.000000E-01,         5.000000E-01
X LABEL:DISTANCE (M)
Y LABEL:POS. PHASE DURATION (SEC)
NEXT FILE:
LAST FILE:



SOF
SOC   1.00000
        3.166618E+01,        1.698062E-01, 1.
        3.586758E+01,        1.676123E-01, 1.
        4.097709E+01,        1.653966E-01, 1.
        4.661290E+01,        1.622538E-01, 1.
        5.302106E+01,        1.562969E-01, 1.
        5.953976E+01,        1.522489E-01, 1.
        6.772501E+01,        1.462920E-01, 1.
        7.938243E+01,        1.365064E-01, 1.
        9.106858E+01,        1.267755E-01, 1.
```

```
1.022578E+02,          1.189754E-01, 1.
1.204031E+02,          1.213731E-01, 1.
1.381767E+02,          1.304027E-01, 1.
1.585795E+02,          1.413083E-01, 1.
1.867815E+02,          1.615283E-01, 1.
2.199990E+02,          1.817484E-01, 1.
2.580125E+02,          2.019794E-01, 1.
2.974114E+02,          2.175642E-01, 1.
3.548549E+02,          2.386894E-01, 1.
4.325813E+02,          2.588218E-01, 1.
5.073091E+02,          2.771768E-01, 1.
5.923530E+02,          2.917907E-01, 1.
7.066882E+02,          3.072877E-01, 1.
8.577089E+02,          3.227410E-01, 1.
1.054455E+03,          3.353473E-01, 1.
1.341672E+03,          3.478660E-01, 1.
1.699712E+03,          3.575815E-01, 1.
2.018736E+03,          3.637094E-01, 1.
2.346548E+03,          3.670779E-01, 1.
2.739290E+03,          3.694974E-01, 1.
EOC
EOF
```

STEP 3.

The data is examined and a functional form chosen for the fit. Then program FITTER is used to obtain the coefficients for which that function best approximates the given data.

Fig. 5 shows a plot of the data from data file DURPP.2DF. (This figure was produced by the program HP7225.)

A functional form which suggests itself is

$$Y = \frac{a}{(X/b)^{c} + 1} + \frac{d}{(X/g)^{-h} + 1}$$

where Y = positive phase duration in seconds

X = distance from burst in meters.

The term $a / [(X/b)^{c} + 1]$ governs the limit of small X ($X \ll b,g$) and defines the left side of the graph; likewise the term $d / [(X/g)^{-h} + 1]$ governs the limit of large X ($X \gg b,g$) and defines the right side of the graph. (See fig. 5.)

A linearization of parameters technique is used to determine the coefficients a, b, c, d, g, and h. This method requires initial estimates for the values of the coefficients, which we may set by examining the asymptotic behavior of the function.

For $X \ll b,g$, Y tends to a = .17 seconds (see fig. 4 or 5)

For $X \gg b,g$, Y tends to d = .375 seconds

When X = b, Y = a/2 (neglecting the second term in the function) which we estimate to occur at X = b = 400 ft = 122 meters.

When X = g, Y = d/2 (neglecting the first term in the function) which we estimate to occur at X = g = 800 ft = 244 meters.

Finally, as initial guesses for coefficients c and h we choose 1.

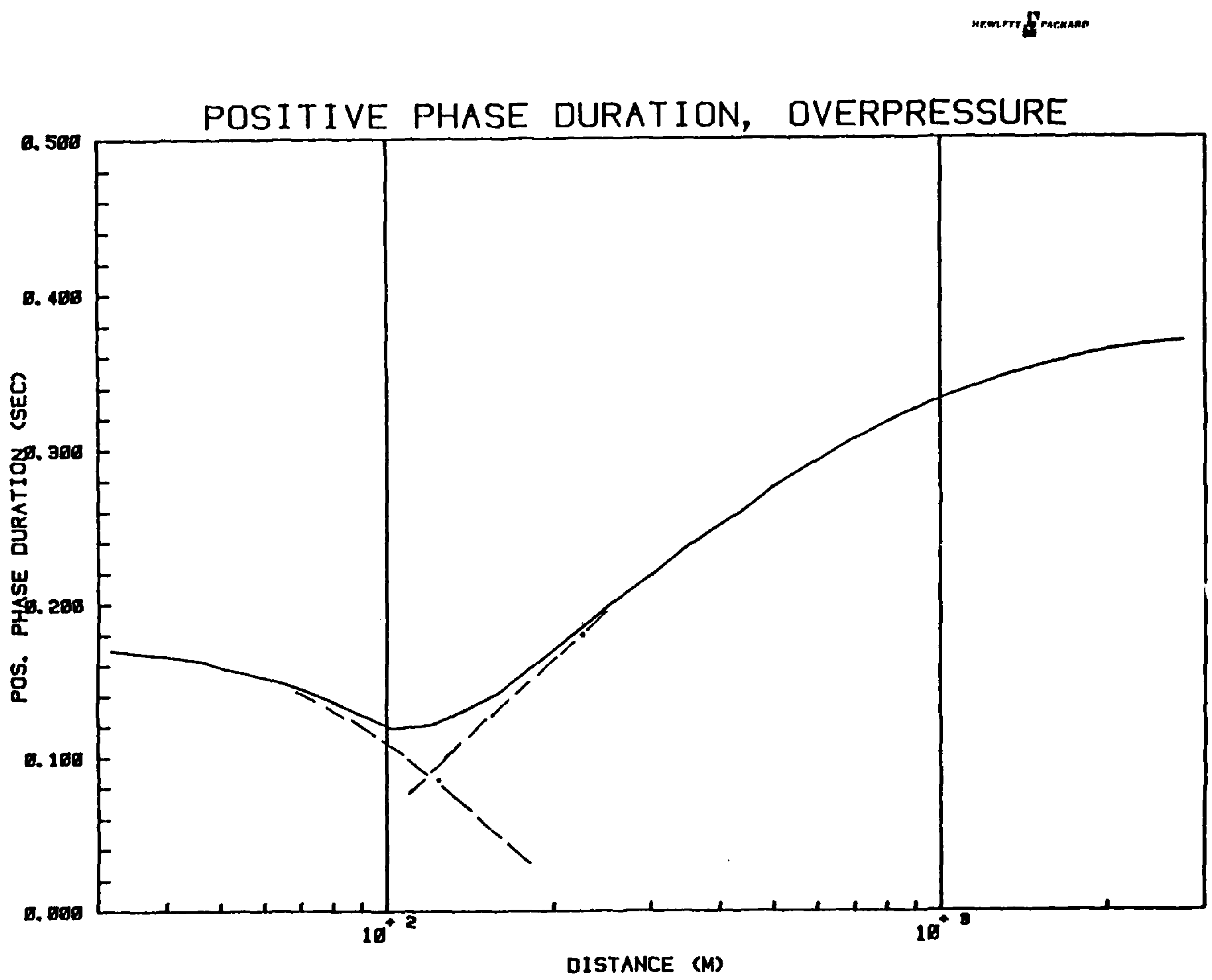

HEWLETT PACKARD
POSITIVE PHASE DURATION, OVERPRESSURE
0.500
0.400
0.300
0.200
0.100
0.000
POS. PHASE DURATION (SEC)
10+2
10+3
DISTANCE (M)

Figure 5.

Now program FITTER is used to optimize these coefficients. First, the functional form to be used, which is rather specialized, is set up in a FORTRAN subroutine to be called by the main program. This subroutine will be used for each of the two terms in the function.

```
      FUNCTION USER3(I,X)                    ! USER3.PPD
C
C     USER-DEFINED ROUTINE FOR POS. PHASE DURATION FIT
C
      DOUBLE PRECISION PI
      REAL COEFF(4,13,10),DATA(2,4,101),SCRTCH(3,2,15)
      INTEGER FUNCT(4,14),INFO(10)
      BYTE CLEAR(7),CHAR,CHR(4),JUNK
      REAL EXT(6)
C
      COMMON/ALL/COEFF,DATA,SCRTCH,FUNCT,INFO,CLEAR,CHR,JUNK,PI,ZPOINT
      COMMON/USER/EXT
C
      DATA EXT(3)/'PPD'/
C
C        F(X) = A / ((X/B)^C + 1)
C
      USER3=COEFF(1,I,1)/((X/COEFF(1,I,2))**COEFF(1,I,3) + 1.)
C
      RETURN
      END
```

The procedure used to optimize the coefficients is an iterative one which requires that some of the coefficients be held fixed while the other are allowed to vary. If at first the coefficients a, b, d, and g are fixe and c and h are optimized, we get the following results from the FITTER:

iteration	a	b	c	d	g	h	RMS relative erro
0	.17	122.	1.000	.375	244.	1.000	
1	.17	122.	3.319	.375	244.	2.199	.1313
2	.17	122.	3.022	.375	244.	2.155	.1307
3	.17	122.	2.830	.375	244.	2.125	.1309
4	.17	122.	2.935	.375	244.	2.137	.1315
5	.17	122.	2.879	.375	244.	2.130	.1315

Now, fixing the values of c and h as they have stabilized, and allowing a, b, d, and g to vary:

iteration	a	b	c	d	g	h	RMS relative erro
6	.1641	104.4	2.879	.3565	253.1	2.130	.0421
7	.1675	101.6	2.879	.3564	253.2	2.130	.0409
8	.1679	101.2	2.879	.3564	252.8	2.130	.0407
9	.1679	101.1	2.879	.3563	252.7	2.130	.0406

Finally, c and h are again allowed to vary, to achieve the optimum values:

iteration	a	b	c	d	g	h	RMS relative erro
10	.1641	104.4	2.552	.3565	253.1	1.978	.0415
11	.1641	104.4	2.594	.3565	253.1	1.991	.0406
12	.1641	104.4	2.590	.3565	253.1	1.990	.0406

with stable values. Program FITTER gives the point-by-point error analysis:

I	X	Y	F	F-Y	(F-Y)/Y
1	3.16662E+01	1.69806E-01	1.65635E-01	-4.17146E-03	-2.45660E-02
2	3.58676E+01	1.67612E-01	1.64364E-01	-3.24813E-03	-1.93788E-02
3	4.09771E+01	1.65397E-01	1.62452E-01	-2.94496E-03	-1.78055E-02
4	4.66129E+01	1.62254E-01	1.59921E-01	-2.33309E-03	-1.43793E-02
5	5.30211E+01	1.56297E-01	1.56612E-01	3.15145E-04	2.01632E-03
6	5.95398E+01	1.52249E-01	1.52937E-01	6.87972E-04	4.51873E-03
7	6.77250E+01	1.46292E-01	1.48172E-01	1.88008E-03	1.28516E-02
8	7.93824E+01	1.36506E-01	1.41775E-01	5.26822E-03	3.85932E-02
9	9.10686E+01	1.26776E-01	1.36586E-01	9.81008E-03	7.73815E-02
10	1.02258E+02	1.18975E-01	1.33253E-01	1.42777E-02	1.20005E-01
11	1.20403E+02	1.21373E-01	1.31606E-01	1.02327E-02	8.43075E-02
12	1.38177E+02	1.30403E-01	1.34130E-01	3.72693E-03	2.85802E-02
13	1.58579E+02	1.41308E-01	1.40914E-01	-3.94389E-04	-2.79098E-03
14	1.86781E+02	1.61528E-01	1.54592E-01	-6.93622E-03	-4.29412E-02
15	2.19999E+02	1.81748E-01	1.73536E-01	-8.21231E-03	-4.51851E-02
16	2.58012E+02	2.01979E-01	1.95495E-01	-6.48487E-03	-3.21066E-02
17	2.97411E+02	2.17564E-01	2.16485E-01	-1.07932E-03	-4.96093E-03
18	3.54855E+02	2.38689E-01	2.42435E-01	3.74570E-03	1.56928E-02
19	4.32581E+02	2.58822E-01	2.69128E-01	1.03061E-02	3.98192E-02
20	5.07309E+02	2.77177E-01	2.87652E-01	1.04756E-02	3.77939E-02
21	5.92353E+02	2.91791E-01	3.02795E-01	1.10040E-02	3.77120E-02
22	7.06688E+02	3.07288E-01	3.16665E-01	9.37760E-03	3.05173E-02

23	8.57709E+02	3.22741E-01	3.28223E-01	5.48199E-03	1.69857E-02
24	1.05446E+03	3.35347E-01	3.37114E-01	1.76695E-03	5.26901E-03
25	1.34167E+03	3.47866E-01	3.44144E-01	-3.72222E-03	-1.07002E-02
26	1.69971E+03	3.57581E-01	3.48603E-01	-8.97881E-03	-2.51098E-02
27	2.01874E+03	3.63709E-01	3.50801E-01	-1.29081E-02	-3.54901E-02
28	2.34655E+03	3.67078E-01	3.52212E-01	-1.48655E-02	-4.04967E-02
29	2.73929E+03	3.69497E-01	3.53293E-01	-1.62042E-02	-4.38548E-02

ERROR IS: 4.06593E-02 RMS REL ERROR

Since this equation will be used in a calculator program with limited space available, it is important to minimize the number of significant digits required in the coefficients. The FITTER allows us to round the values of the coefficients, and examine the resulting errors.

a	b	c	d	g	h
.17	100.	2.6	.36	260.	-2.

with the errors:

I	X	Y	F	F-Y	(F-Y)/Y
1	3.16662E+01	1.69806E-01	1.67121E-01	-2.68531E-03	-1.58140E-02
2	3.58676E+01	1.67612E-01	1.65670E-01	-1.94208E-03	-1.15868E-02
3	4.09771E+01	1.65397E-01	1.63508E-01	-1.88828E-03	-1.14167E-02
4	4.66129E+01	1.62254E-01	1.60669E-01	-1.58489E-03	-9.76795E-03
5	5.30211E+01	1.56297E-01	1.56977E-01	6.79880E-04	4.34993E-03
6	5.95398E+01	1.52249E-01	1.52889E-01	6.40094E-04	4.20426E-03
7	6.77250E+01	1.46292E-01	1.47596E-01	1.30381E-03	8.91236E-03
8	7.93824E+01	1.36506E-01	1.40471E-01	3.96480E-03	2.90448E-02
9	9.10686E+01	1.26776E-01	1.34627E-01	7.85197E-03	6.19360E-02
10	1.02258E+02	1.18975E-01	1.30760E-01	1.17846E-02	9.90511E-02
11	1.20403E+02	1.21373E-01	1.28442E-01	7.06901E-03	5.82420E-02
12	1.38177E+02	1.30403E-01	1.30519E-01	1.16229E-04	8.91309E-04
13	1.58579E+02	1.41308E-01	1.36996E-01	-4.31184E-03	-3.05137E-02
14	1.86781E+02	1.61528E-01	1.50528E-01	-1.10002E-02	-6.81009E-02
15	2.19999E+02	1.81748E-01	1.69595E-01	-1.21530E-02	-6.68672E-02
16	2.58012E+02	2.01979E-01	1.91946E-01	-1.00337E-02	-4.96771E-02
17	2.97411E+02	2.17564E-01	2.13492E-01	-4.07198E-03	-1.87162E-02
18	3.54855E+02	2.38689E-01	2.40335E-01	1.64548E-03	6.89379E-03
19	4.32581E+02	2.58822E-01	2.68153E-01	9.33143E-03	3.60535E-02
20	5.07309E+02	2.77177E-01	2.87568E-01	1.03917E-02	3.74912E-02
21	5.92353E+02	2.91791E-01	3.03497E-01	1.17064E-02	4.01190E-02
22	7.06688E+02	3.07288E-01	3.18127E-01	1.08389E-02	3.52728E-02
23	8.57709E+02	3.22741E-01	3.30338E-01	7.59670E-03	2.35381E-02
24	1.05446E+03	3.35347E-01	3.39738E-01	4.39104E-03	1.30940E-02
25	1.34167E+03	3.47866E-01	3.47169E-01	-6.97374E-04	-2.00472E-03
26	1.69971E+03	3.57581E-01	3.51876E-01	-5.70506E-03	-1.59546E-02
27	2.01874E+03	3.63709E-01	3.54195E-01	9.51481E-03	-2.61605E-02

28	2.34655E+03	3.67078E-01	3.55680E-01	-1.13975E-02	-3.10493E-02
29	2.73929E+03	3.69497E-01	3.56817E-01	-1.26806E-02	-3.43184E-02

ERROR IS: 3.75476E-02 RMS REL ERROR

which are generally acceptable.

STEP 4.

A plot of the fitting function is made against the original graph to visually verify the fit.

Using programs FITTER and DERM, a data file containing the values of our fitting function over the range of the source graph was created:

```
FILE:DATA.1DF    DATE:05-DEC-79 13:55
NAME:POS. PHASE FIT, OVERPRESSURE
TYPE:100
X(MIN,MAX):          1.000000E+02,        1.000000E+04
Y(MIN,MAX):          0.000000E-01,        5.000000E-01
X LABEL:DISTANCE (FT)
Y LABEL:POS. PHASE DURATION (SEC)
NEXT FILE:
LAST FILE:




SOF
SOC  0.000000
        1.000000E+02,        1.674751E-01, 1.
        1.047615E+02,        1.670384E-01, 1.
        1.097498E+02,        1.665415E-01, 1.
        1.149756E+02,        1.659782E-01, 1.
        1.204502E+02,        1.653418E-01, 1.
        1.261855E+02,        1.646254E-01, 1.
        1.321939E+02,        1.638220E-01, 1.
        1.384883E+02,        1.629248E-01, 1.
        1.450825E+02,        1.619272E-01, 1.

         .

         .

         .

        6.579140E+03,        3.541182E-01, 1.
        6.892408E+03,        3.546310E-01, 1.
        7.220593E+03,        3.550998E-01, 1.
        7.564404E+03,        3.555282E-01, 1.
        7.924587E+03,        3.559196E-01, 1.
        8.301918E+03,        3.562773E-01, 1.
        8.697218E+03,        3.566038E-01, 1.
        9.111340E+03,        3.569020E-01, 1.
        9.545179E+03,        3.571743E-01, 1.
        9.999677E+03,        3.574228E-01, 1.
EOC
EOF
```

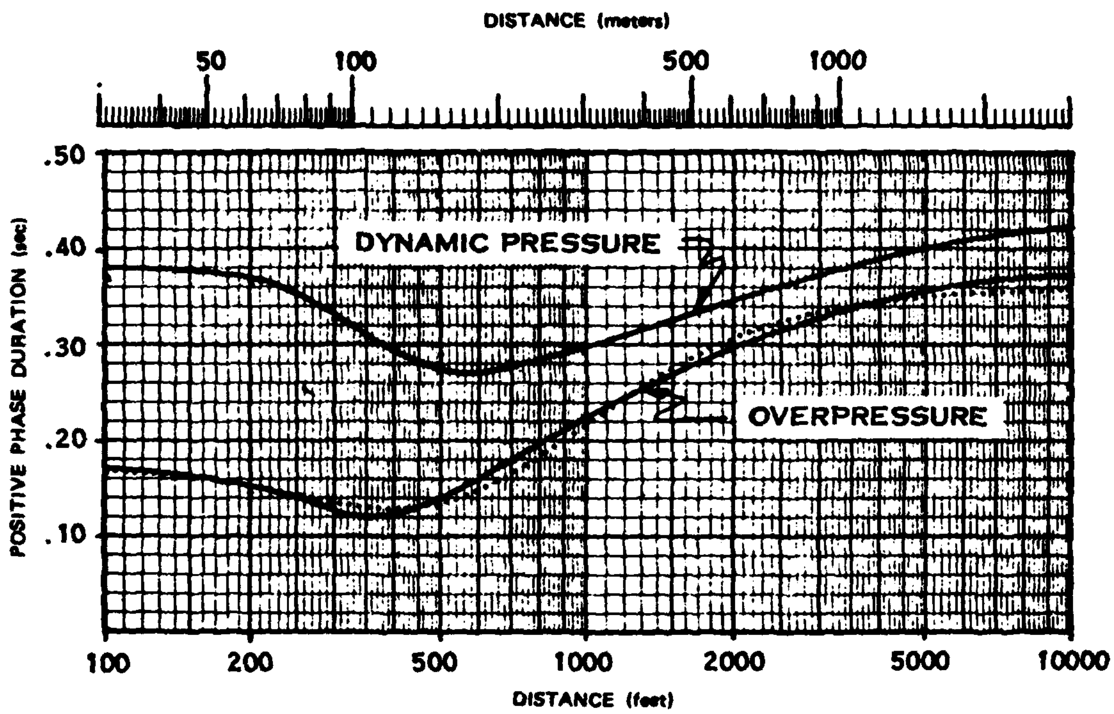
The plotter program HP7225 scales and orients the axes for the plot in accordance with the data file parameters and additional user input:

```
ENTER PLOT FILE NAME:  DATA.1DF

OPTIONS ? ?
THE FOLLOWING OPTIONS ARE AVAILABLE
     SYM  - - - - - - SYMBOL PT. PLOT MODE
     ROT  - - - - - - 90 DEGREE PLOT ROTATION
     LINE - - - - - - CONTINUOUS LINE MODE
     AXES - - - - - - CHANGE AXES TYPES
     SIZE - - - - - - CHANGE GRAPH SIZE
     MIN  - - - - - - CHANGE GRAPH MIN OR MAX
     MAX  - - - - - - CHANGE GRAPH MIN OR MAX
     INFO - - - - - - DISPLAYS PROGRAM USER INFORMATION
     SET  - - - - - - SET GRAPH AXES FRAME LIMITS

OPTIONS ? ROT

OPTIONS ? SET

PLEASE POSITION PEN FOR GRAPH LOWER LEFT CORNER
HIT 'RETURN' OR 'ENTER' WHEN POSITIONED

PEN POSITION:

X =  4626
Y =  7000

PLEASE POSITION PEN FOR GRAPH UPPER RIGHT CORNER
HIT 'RETURN' OR 'ENTER' WHEN POSITIONED

PEN POSITION:

X =  7346
Y =  1520
```

The curve itself is now plotted, with a dotted line:

```
OPTIONS ?                                (carriage return)
READY FOR CURVE # 1 ? L                  (indicates a request for line type)
ENTER LINE TYPE 0 THROUGH 6.
FOR CONTINUOUS LINE, JUST HIT A CARRIAGE RETURN
LINE TYPE? ===> 0
```

The curve is then plotted, and the result is fig. 6. A comparison of the original digitized data with the final fit may also be made, with the result of fig. 7 (the solid line represents the fitting function, whil the dots are individual digitization points). We have arrived at a fairly accurate fit, with pleasingly short coefficients.



Duration of Positive Overpressure and Dynamic Pressure Phases for a 1 kt Free Air Burst in a Standard Sea Level Atmosphere

Figure 6

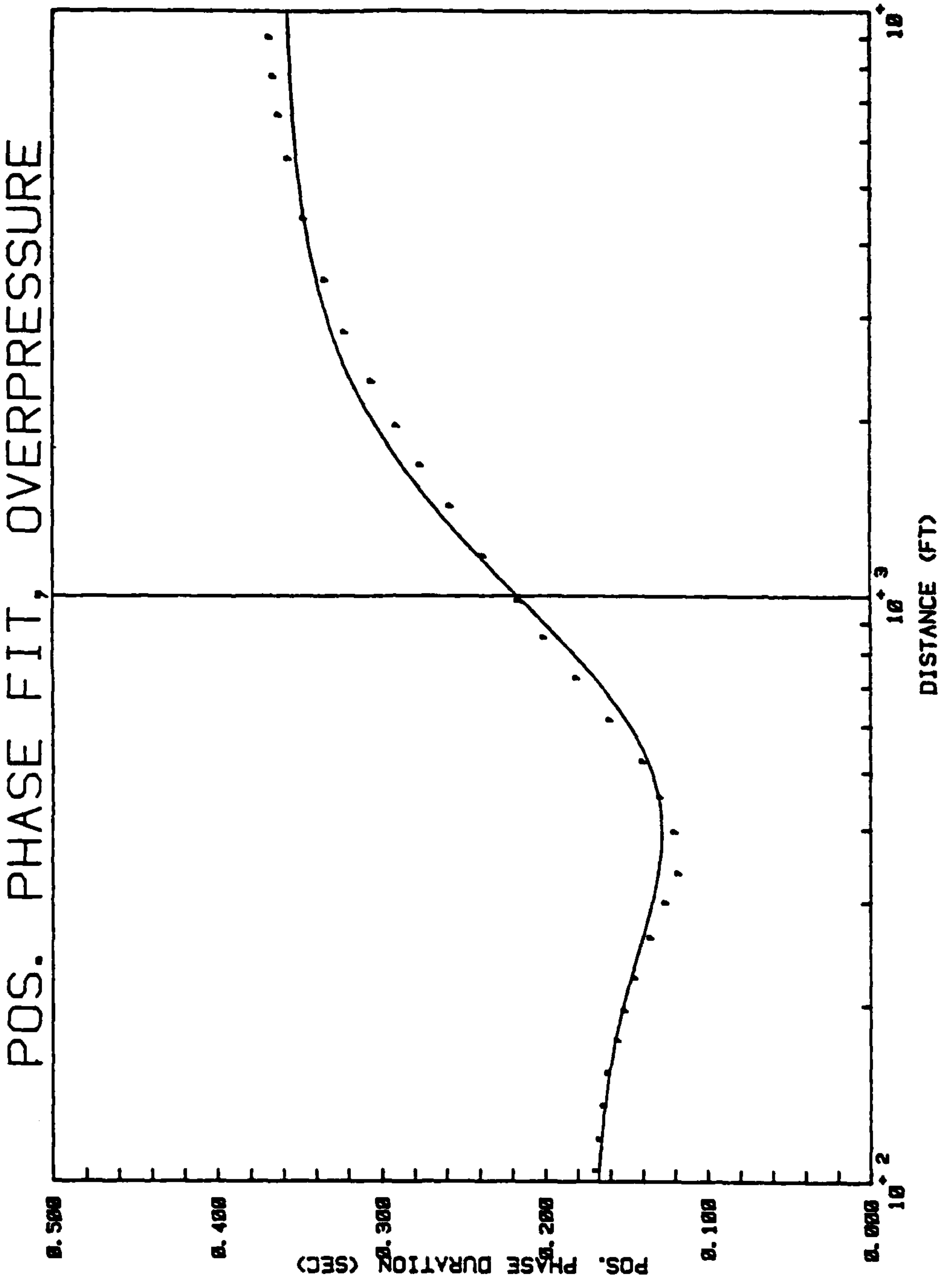

POS. PHASE FIT, OVERPRESSURE
POS. PHASE DURATION (SEC)
DISTANCE (FT)
0.000
0.100
0.200
0.300
0.400
0.500
10+2
10+3
10+4

Figure 7.

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